Additional Topics for LHC

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Tevatron Accelerator Studies Workshop

Fermilab

13-14.01.2010

First LHC Beam Experience

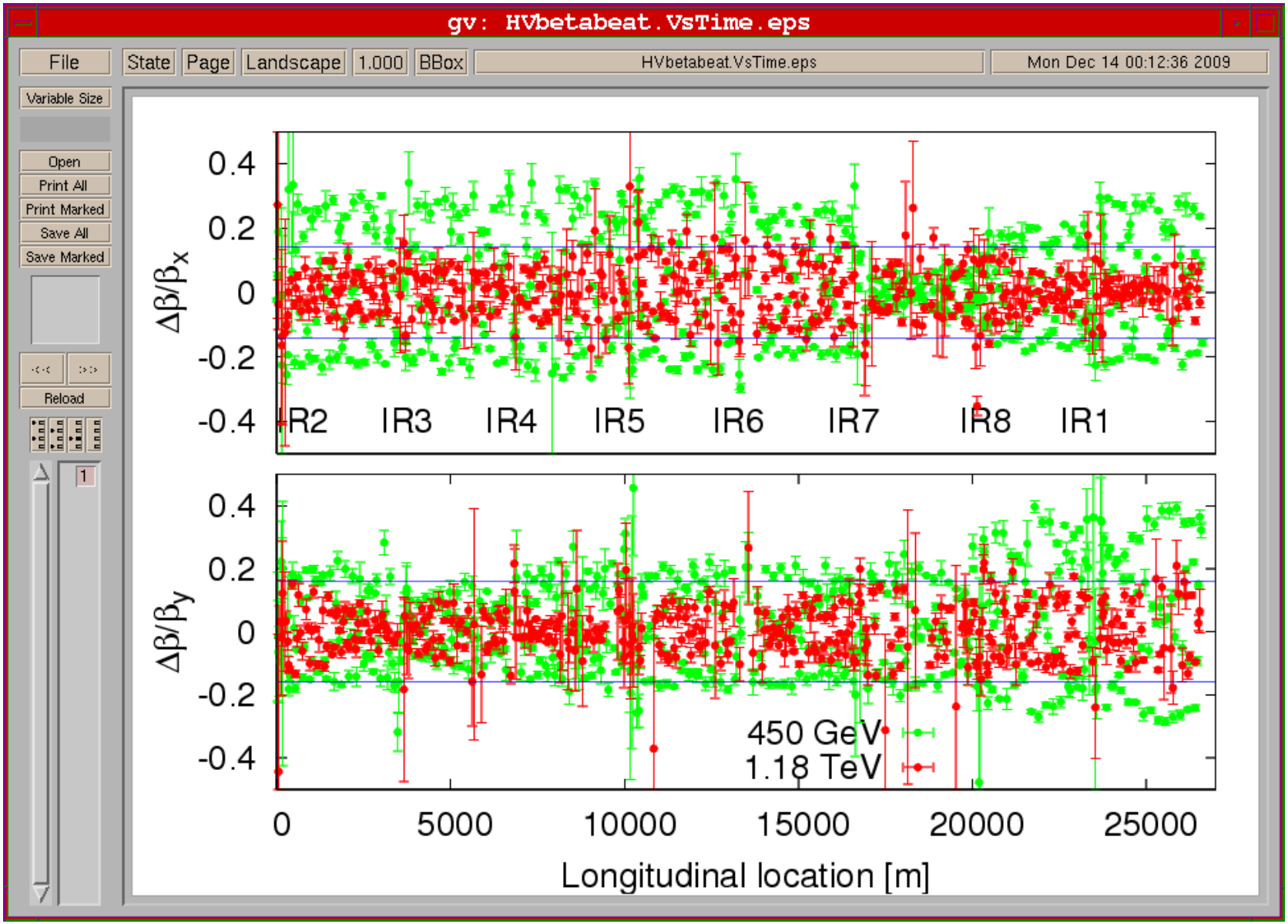
- After long wait time, finally we got an excellent first beam commissioning with LHC, November – December 2009.
- Here to represent LHC accelerator physics and LHC machine coordination (in addition to collimation role).
- See beam commissioning page:
  - http://www.cern.ch/lhc-commissioning/news/LHC-news.htm
- Summary talk S. Myers for first beam measurements:
  - http://indico.cern.ch/conferenceDisplay.py?confId=76398
- Detailed review of first beam experience and commissioning plan for 2010 next week in Evian (LHC Beam Commissioning Workshop):
  - http://indico.cern.ch/conferenceDisplay.py?confId=76921
- Here just a few slides for your entertainment (courtesy of LHC team)…

Milestones 2009 LHC Beam Commissioning

Date	Day	Achieved
Nov 20	1	Each beam circulating. Key beam instrumentation working.
Nov 23	4	First collisions at 450 GeV. First ramp (reached 560 GeV).
Nov 26	7	Magnetic cycling established (reproducibility).
Nov 27	8	Energy matching.
Nov 29	10	Ramp to 1.18 TeV.
Nov 30	11	Experiment solenoids on.
Dec 04	15	Aperture measurement campaign finished. LHCb and ALICE dipoles on.
Dec 05	16	Machine protection (Injection, Beam dump, Collimators) ready for safe operation with pilots.
Dec 06	17	First collisions with STABLE BEAMS, 4 on 4 pilots at 450 GeV, rates around 1Hz.
Dec 08	19	Ramp colliding bunches to 1.18 TeV
Dec 11	22	Collisions with STABLE BEAMS, 4 on 4 at 450 GeV, > 10^{10} per bunch, rates around 10Hz.
Dec 13	24	Ramp 2 bunches per beam to 1.18 TeV. Collisions for 90mins.
Dec 14	25	Collisions with STABLE BEAMS, 16 on 16 at 450 GeV, > 10^{10} per bunch, rates around 50Hz.
Dec 16	27	Ramp 4 on 4 to 1.18 TeV. Squeeze to 7 m.

LHC Beam Commissioning Team

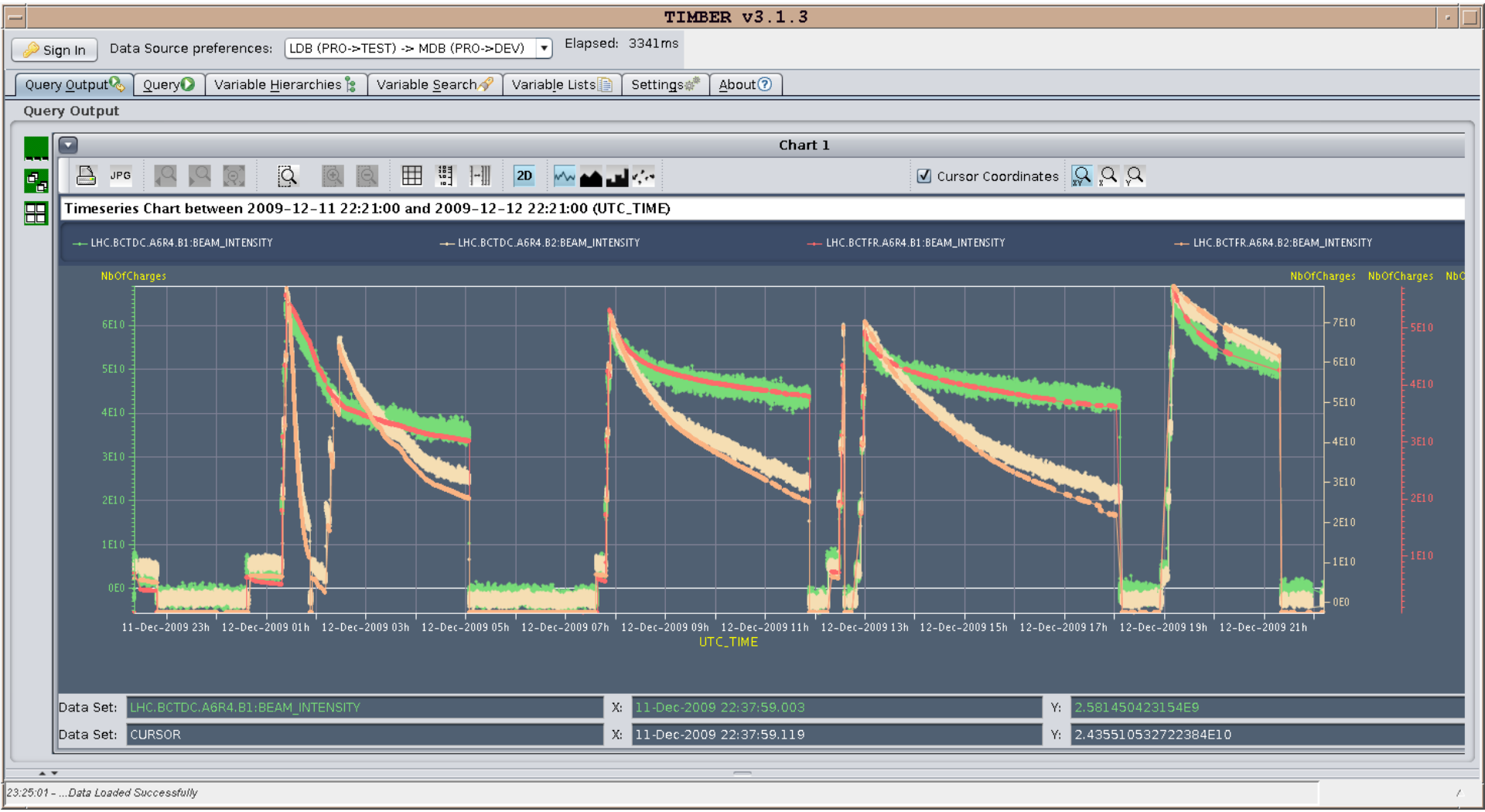
Beta-beat: 450 GeV and 1.18 TeV



Dispersion

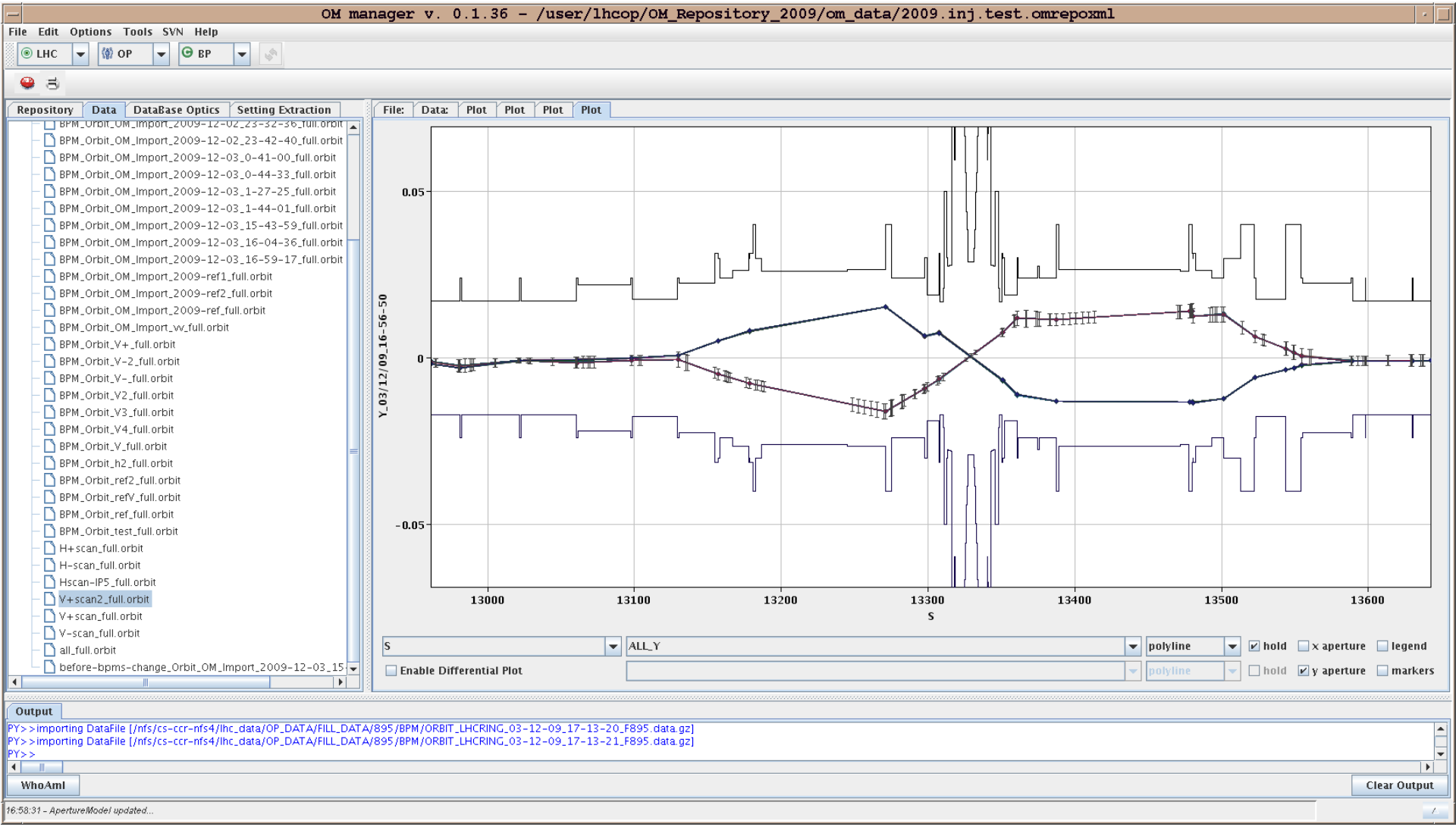

YASP DV LHCRING / NOM_1.2TeV / beam 1
Views
More
21/11/09 20-10-48 - FILL # 877 [21/11/09 20:13:46]
Mean = 1.124 / RMS = 0.816
Disp H [m]
Mu [2pi]
21/11/09 20-10-48 - FILL # 877 [21/11/09 20:13:46]
YASP DV LHCRING / NOM_1.2TeV / beam 2
Views
More
23/11/09 05-07-57 - FILL # 879 [23/11/09 00:54:29]
Mean = 1.104 / RMS = 0.777
Disp H [m]
Mu [2pi]
23/11/09 05-07-57 - FILL # 879 [23/11/09 00:54:29]
Mean = 0.000 / RMS = 0.042
Disp V [m]
Mu [2pi]

13.12.2009: 24 hours running - currents

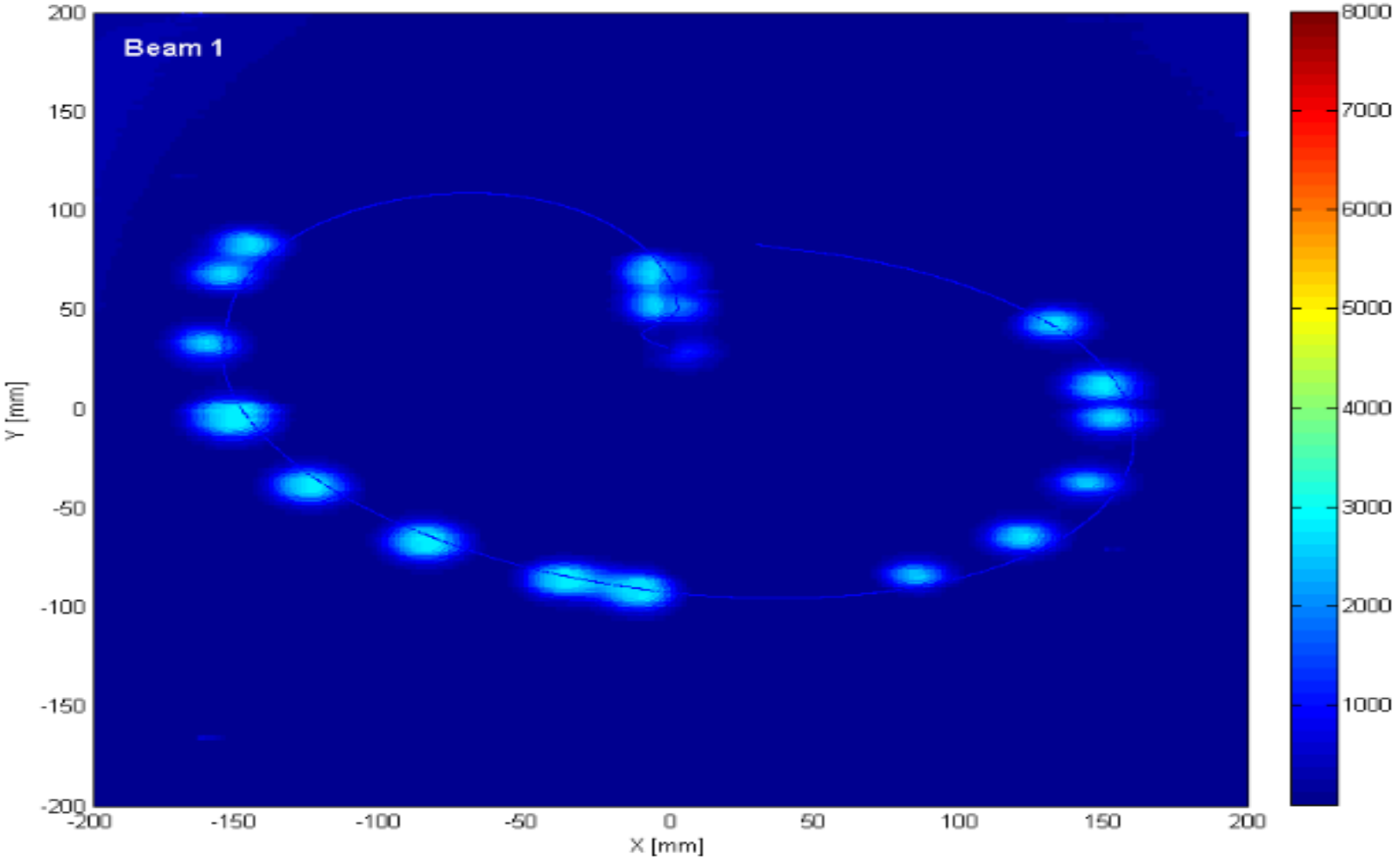


LHC Beam Commissioning Team

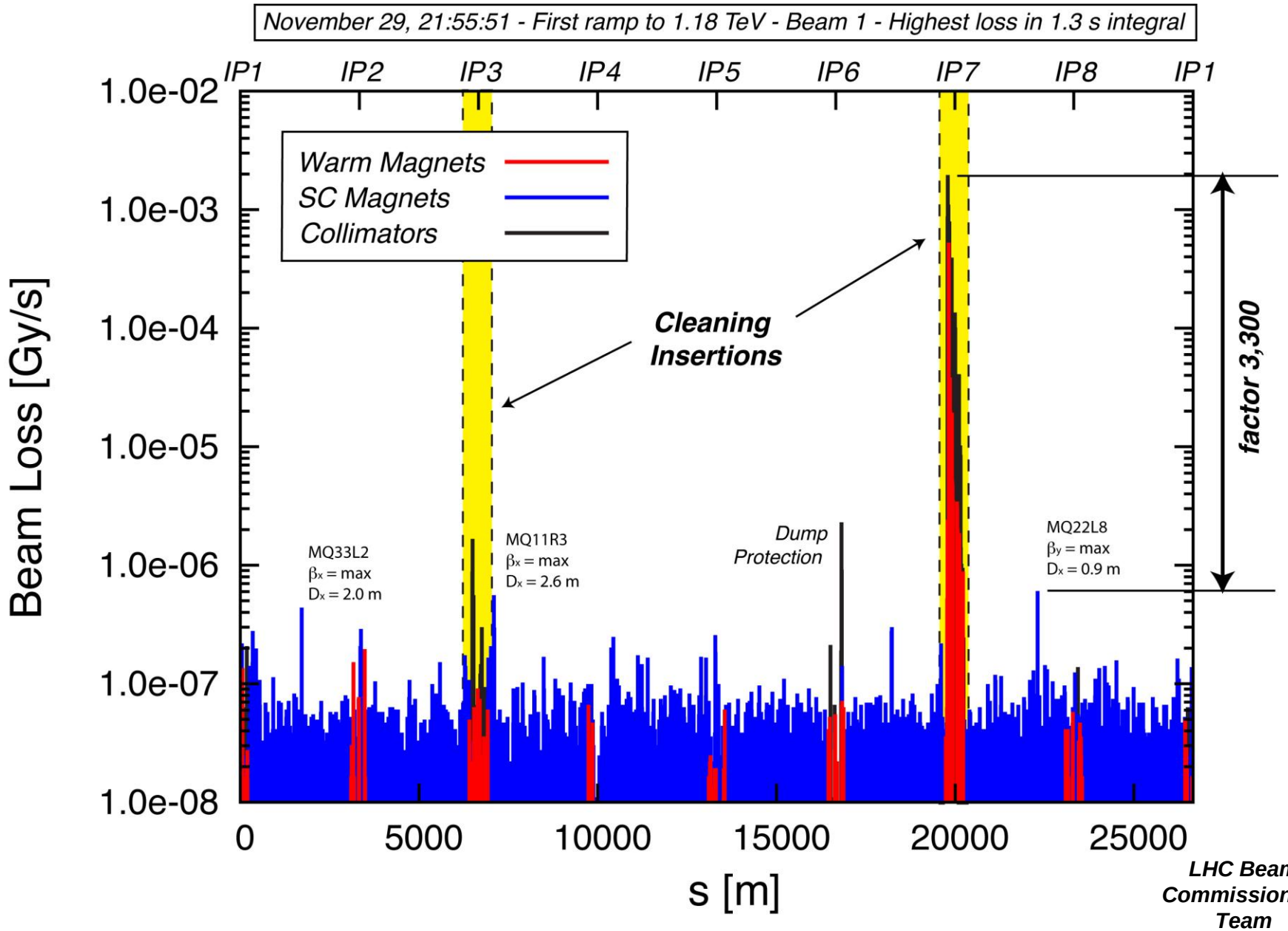
CMS Aperture (vertical)



Beam Dump with 16 Bunches



LHC Collimation Performance (Phase I System)



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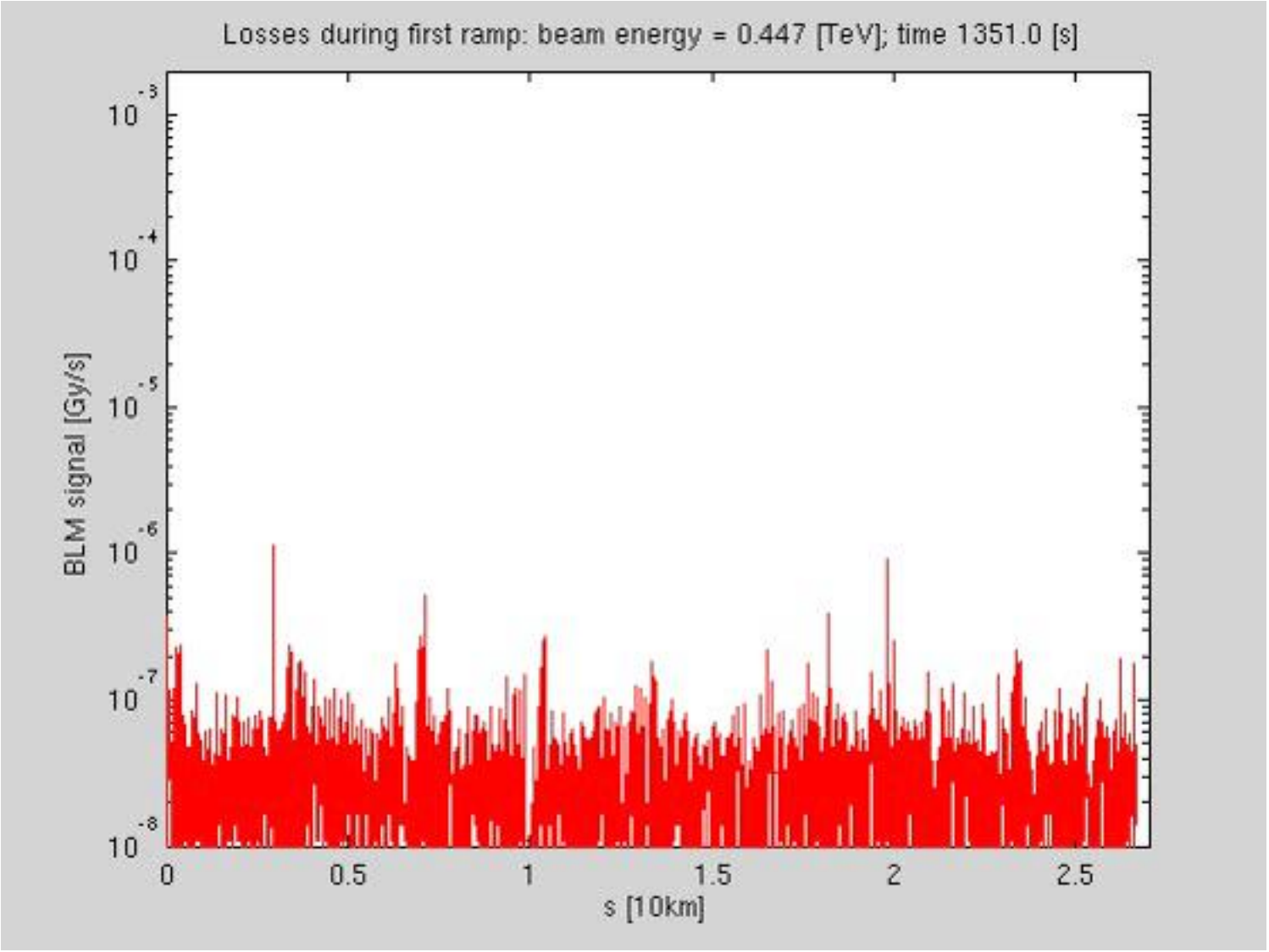
For Fun: Movie of Losses During First Ramp



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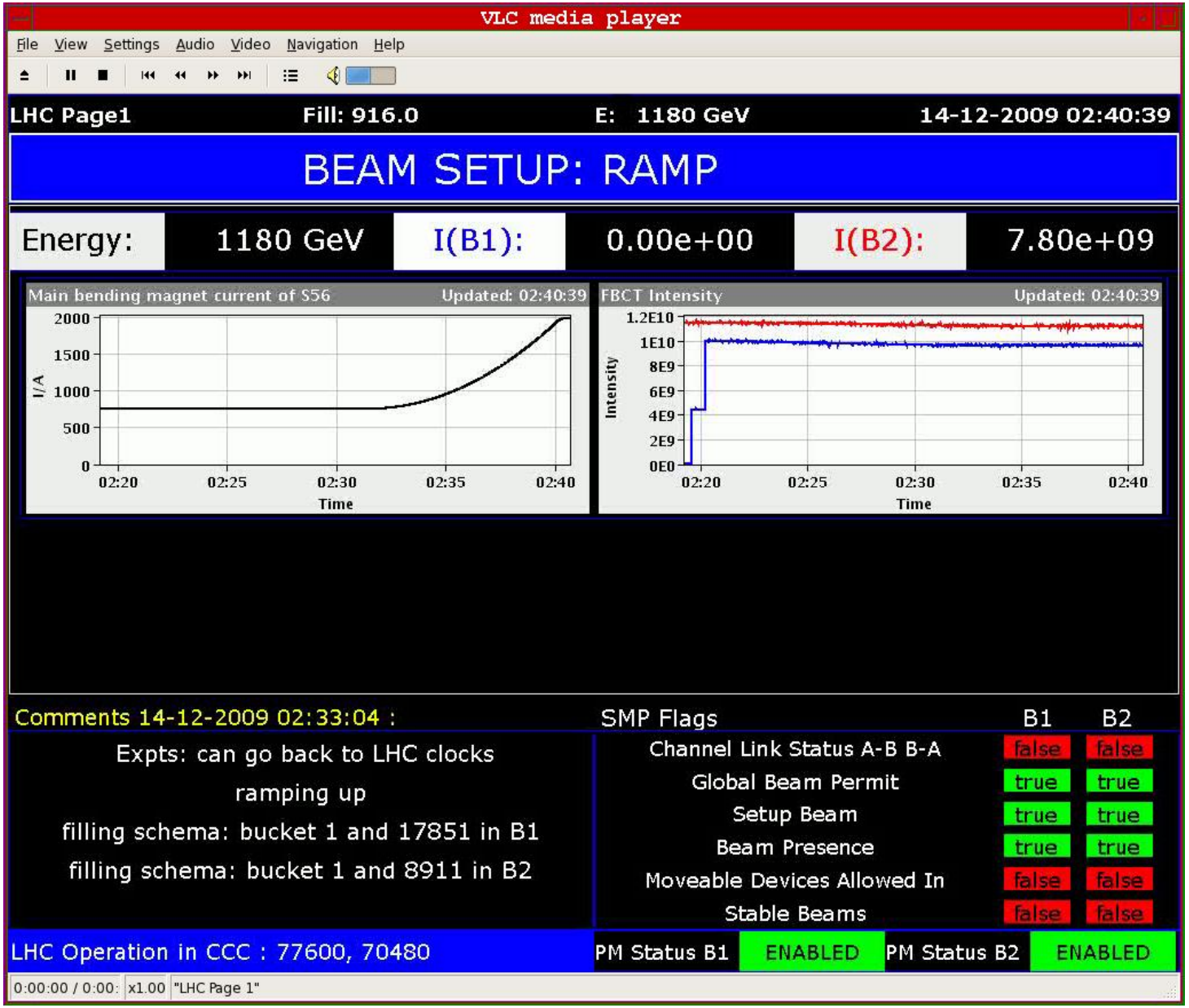
Ramp 2 on 2 to 1.18 TeV: ~no Losses



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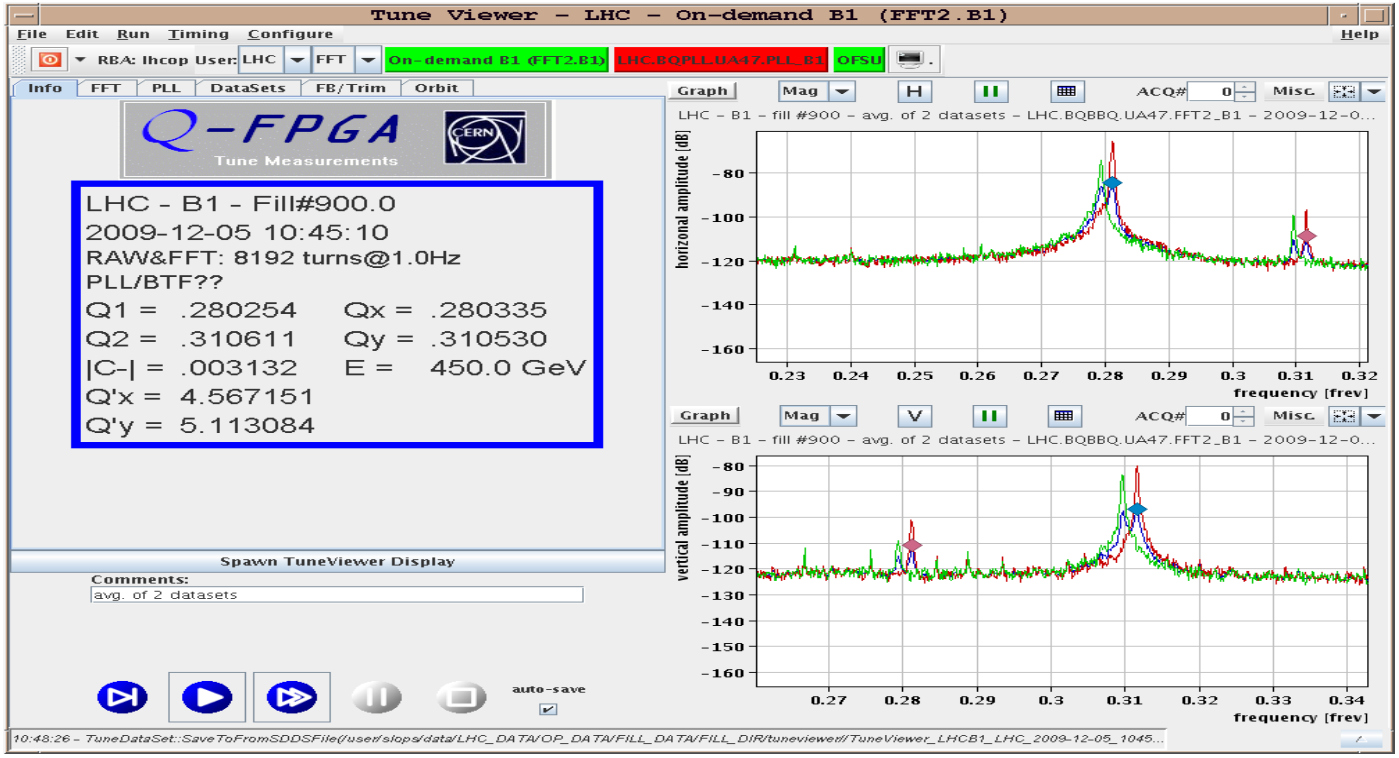
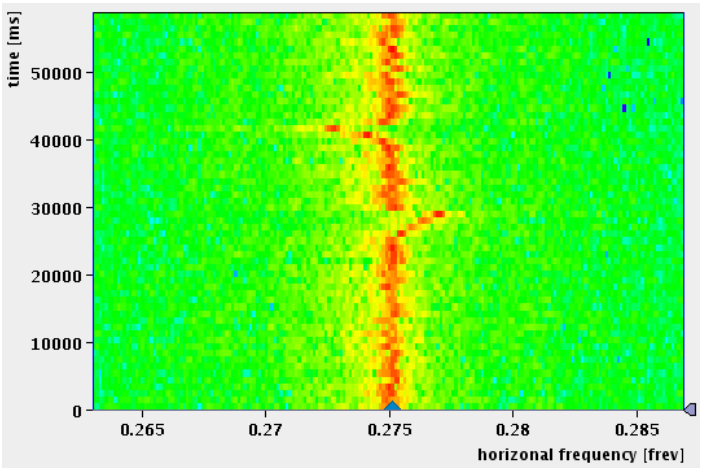
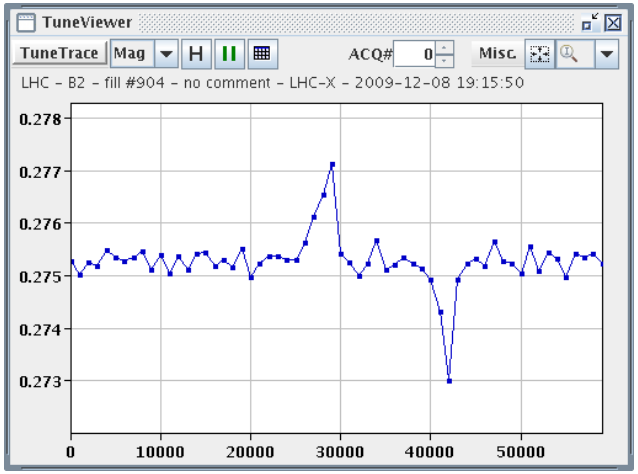
Q Q' C and Q loop







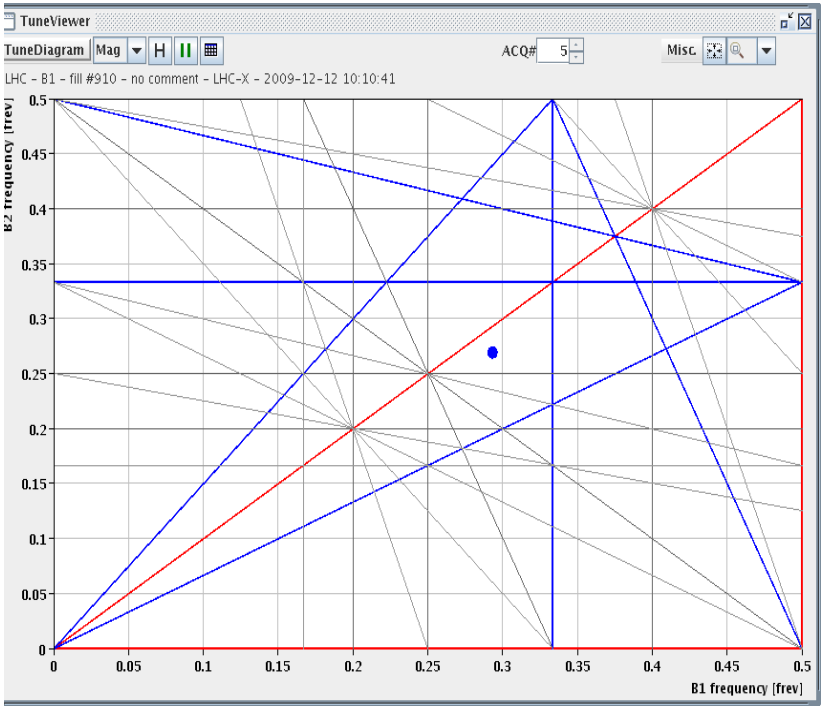
13.12.2009: Tune Adjustments for Beam2

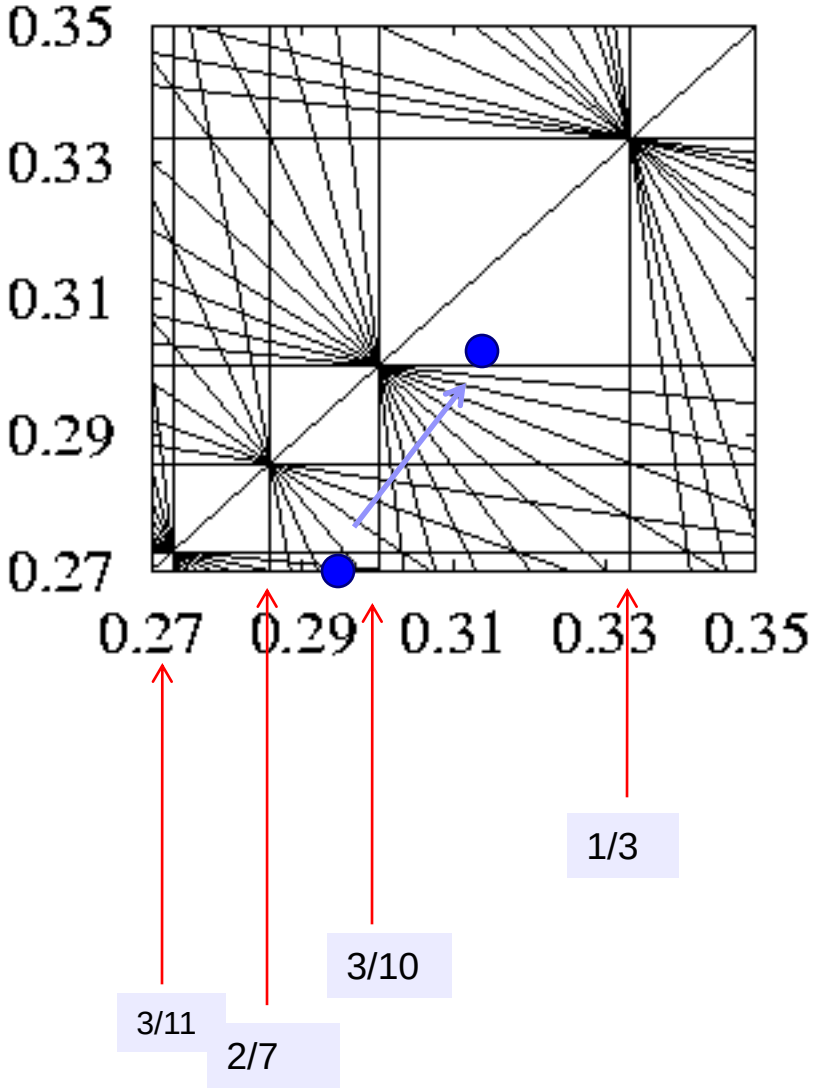
B1: $Q_x = 0.293$, $Q_y = 0.269$; lifetime = 26h

B2: $Q_x = 0.297$, $Q_y = 0.267$; lifetime = **5h**

B1: $Q_x = 0.293$, $Q_y = 0.269$; lifetime = 25h

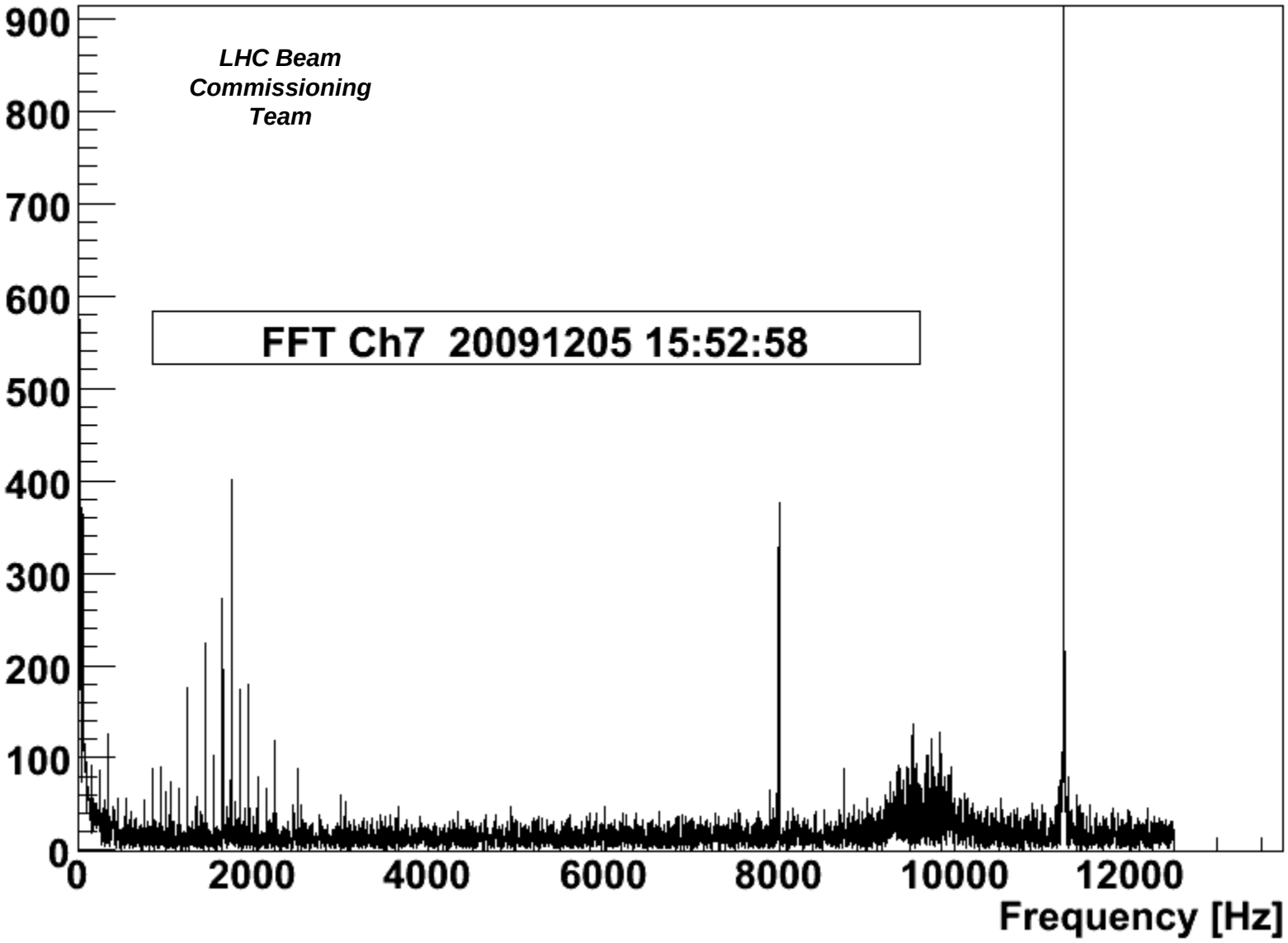
B2: $Q_x = 0.312$, $Q_y = 0.305$; lifetime = **12h**





LHC Beam Commissioning Team

BLM freq spectrum for loss at collimator



Vertical blow up beam 2 (low lifetime)

Focusing back on Tevatron…

- Could continue for many more slides…
- Not the goal of this presentation!
- Sorry, if you are interested and also apologies to the CERN colleagues whose work was not shown.
- Please refer to references given before, if you are interested! Watch Evian workshop on LHC beam commissioning next week:
  - http://indico.cern.ch/conferenceDisplay.py?confId=76921
- Now, let's focus back on Tevatron…

Why tests for LHC at TEVATRON?

- Even as LHC is now available: LHC is not a test bed and machine development time in LHC must be limited.
- Many CERN beam tests for LHC being done at SPS. However, SPS not very close to LHC: Tevatron much better.
- Tevatron: low diffusion beams, super-conducting magnets, collisions and beam-beam effects. All not in SPS!
- Strong CERN interest:
  - Use Tevatron for developing anc advancing generic R&D (crystal collimation, hollow e-beam lens, e-beam lens BB compensator, …) that can then later be used in LHC.
  - Tests with limited risk could be done with last Tevatron beam.
- Still must realize limitations:
  - Difference in beam parameters, machine layout, hardware etc…
  - Require case-by-case analysis if Tevatron experiments are efficient for addressing LHC problems.

General Remarks

- We are collaborating on some topics between CERN and Fermilab. Our support for these studies is a priori clear.
- For additional tests:
  - Do not expect that we already bring a list of CERN requests for Tevatron beam time. Some preliminary ideas later…
  - Were are here at the moment mainly as observers, to understand possibilities and boundary conditions.
  - This meeting was already very useful for us to get more detailed information on the scope of this.
- Take our remarks as preliminary comments and ideas.
- We will go back to CERN and discuss there. List of CERN requests for mid-spring 2010. Update with 2010 beam experience in autumn 2010.
- Total period of ~1-2 weeks of Tevatron beam for CERN?

Comments on Already Proposed Experiments

- Very impressive and important list presented by you.
- Can only reconfirm CERN/LHC support for several discussed topics (not exclusive, not in order of priority):
  - Beam-beam compensation, head-on and LR (if possible).
  - Studies for luminosity leveling (dynamic beta squeeze).
  - Flat bunch scheme, if possible.
  - Collimation efficiency improvement with bent crystals.
  - Indestructible beam scraper with hollow e-beam lens ➔ only LHC scraper solution pursued at the moment.
- Fits well the goal to develop longer term innovative solutions for the LHC and its performance upgrades!
- Priorities will depend on lessons learnt and issues from first LHC run.

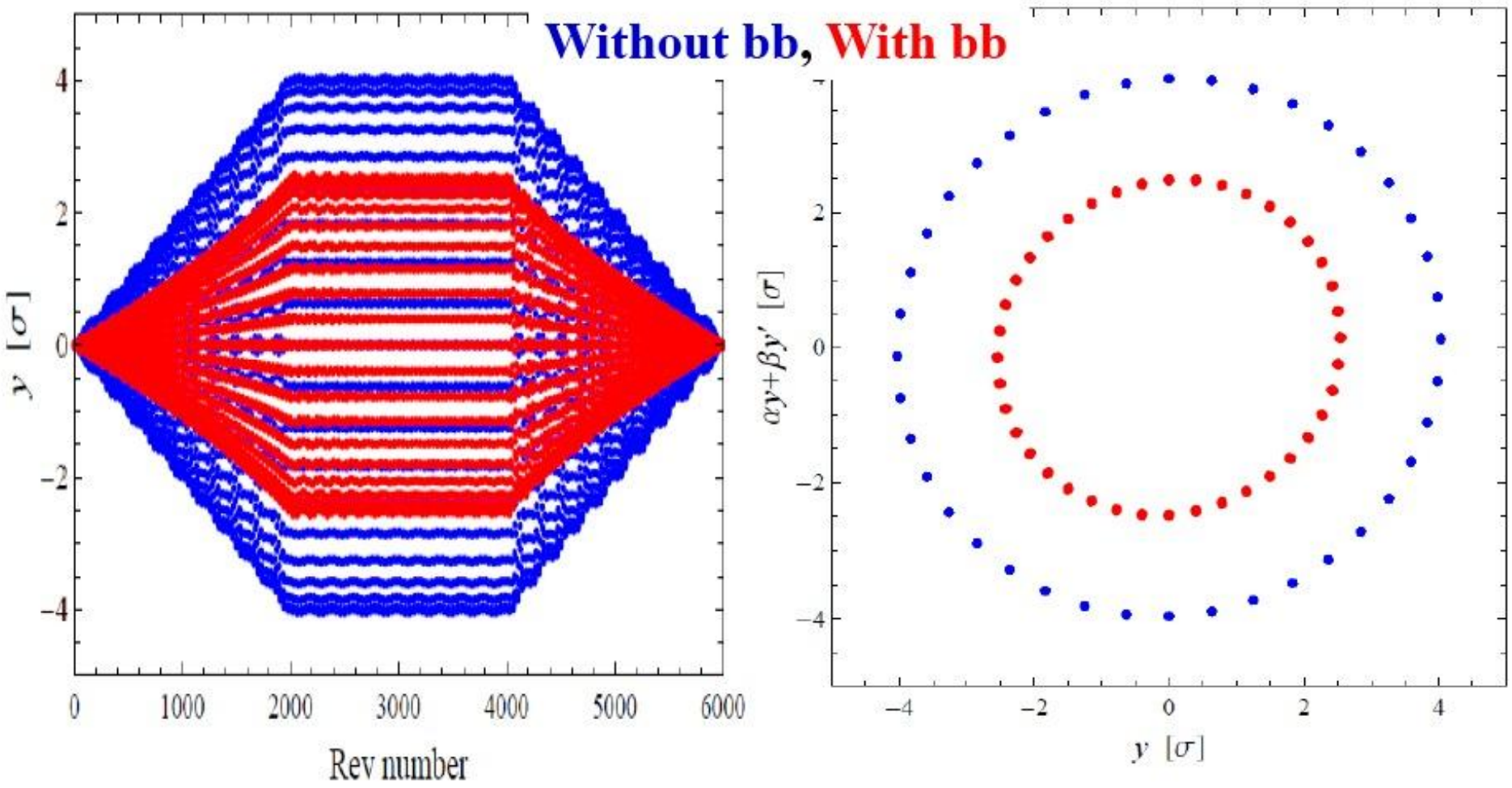
Additional CERN Studies

- Transverse resistive impedance from collimators: measure tune shift versus collimator position. (2 shifts)
- Studying BB resonances using the AC dipole. (3 shifts)
- Generate harmonic transverse perturbation in collision and measure emittance growth for a given frequency. (2 shifts)
- IBS benchmarking. Measure emittance growth versus time for various intensities. (3 shifts)
- Cross a resonance to split the beam and then study the beam-beam interaction between a split and an unsplit beam or two split beams. (3 shifts)
- Measure equilibrium beam distribution by full scraping for reference comparison with LHC (low Tevatron intensity). (2 shifts)
- Test cryogenic beam loss monitors. (done during scraping)
- Backup ideas:
  - Installing the KEK crab cavity in the Tevatron if not approved the SPS.

AC Dipole Simulations (R. Miyamoto)

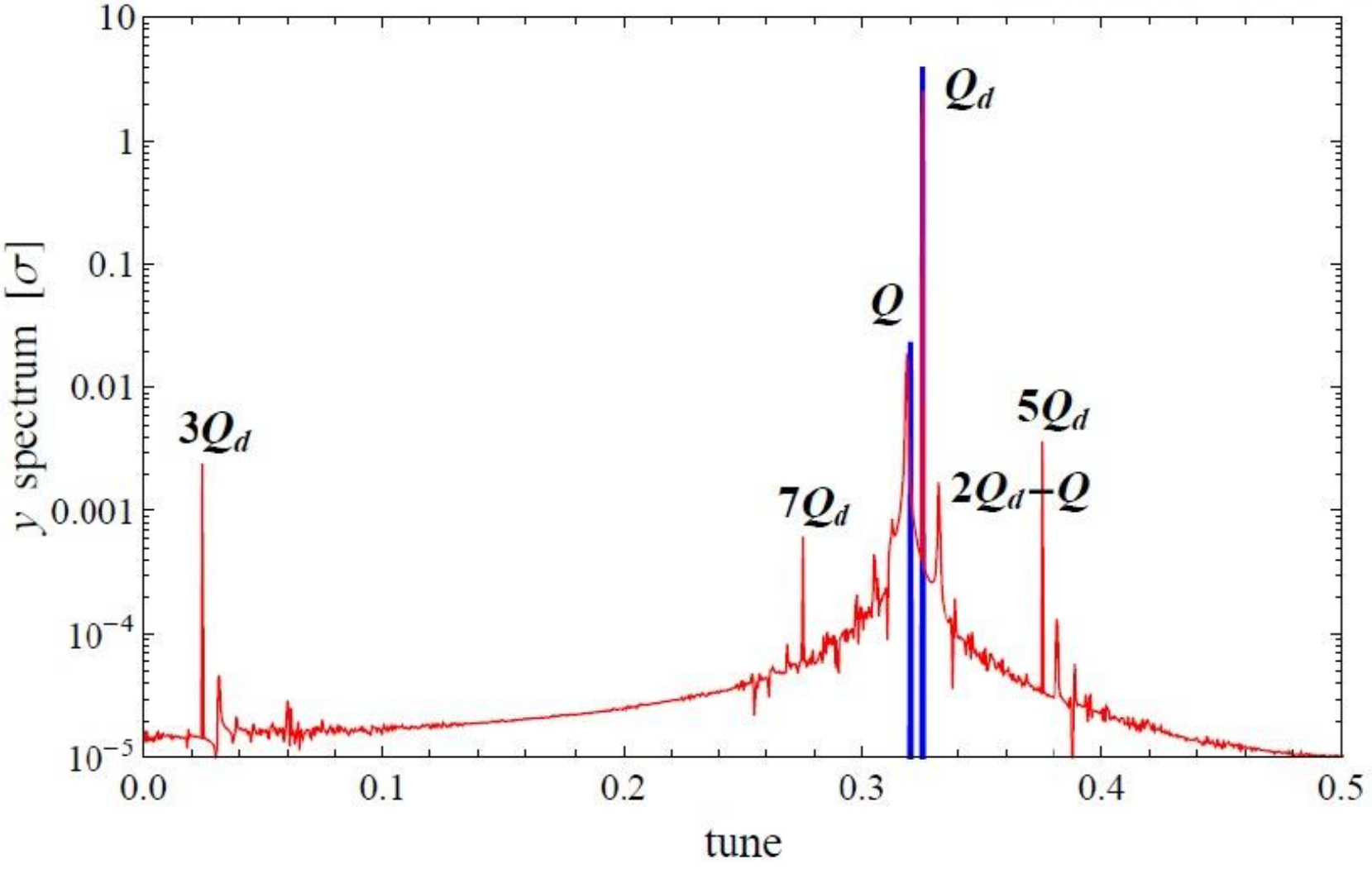
Simulation (a toy model of the LHC):

- AC dipoles (x and y) at IP4
- Thin head-on beam-beam interactions at IP1 and IP5.
- Linear maps with no coupling between IPs and AC dipoles.
- 10k particles.
- $Qx = 0.31$, $Qy = 0.32$
- $Qd = 0.325$ (vertical)
- $\Delta Qbb = 0.005$ (per IP)

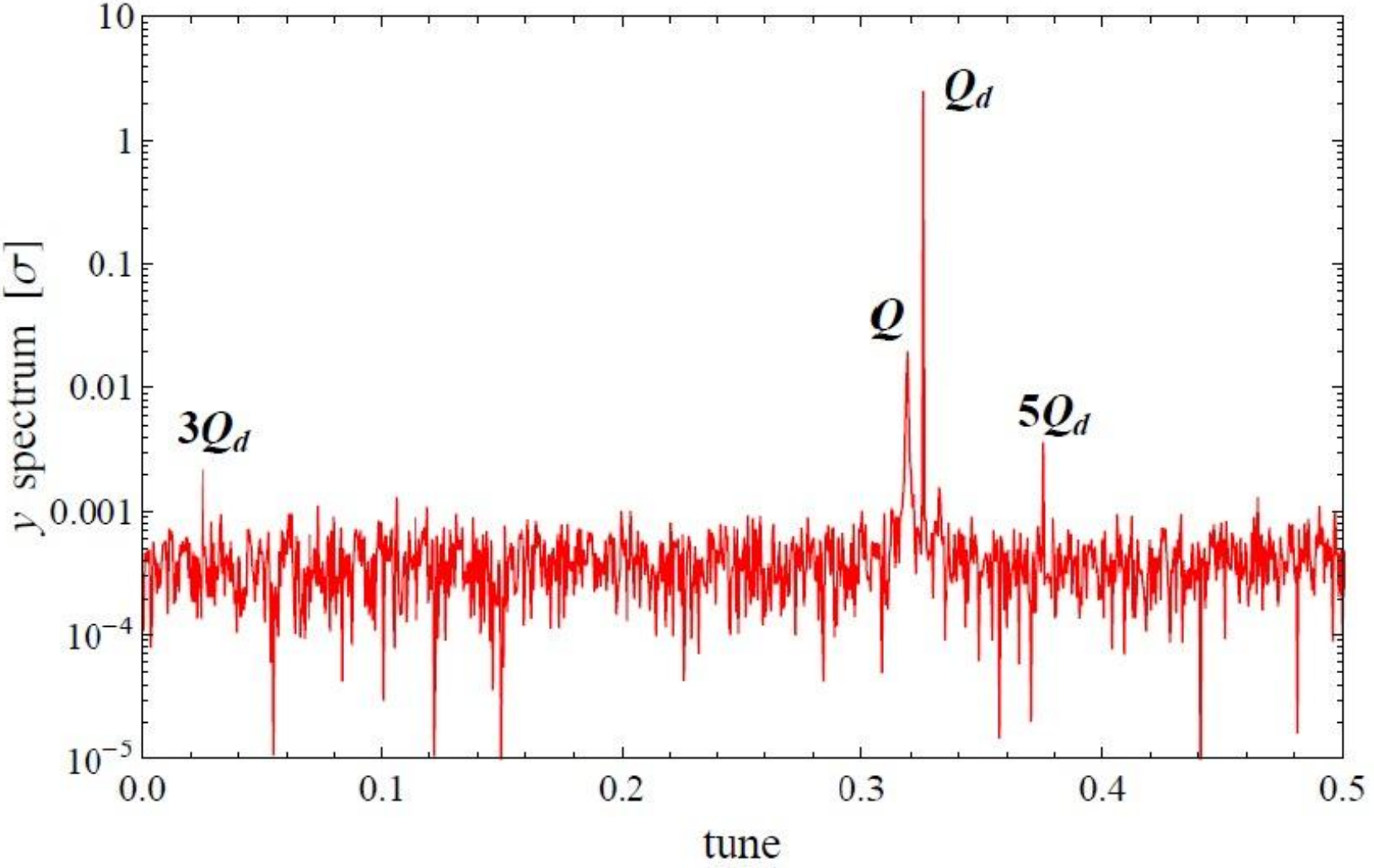


- TBT and Poincare map are not very interesting…
- Strength of the AC dipole are kept the same but the amplitude is modulated due to the tune shift. This may be used to estimate the average tune shift.

Without bb, With bb



Beam-beam resonances may be observed in the spectrum…



Here, I simulated BPM noise. To observe $3Qd$ and $5Qd$, the noise must be as small as a few % of the beam sigma. So, to observe these spectral lines in a real experiments, we may have to have an extreme condition (large beam-beam tune shift, large amplitude, many turns, …).

AC Dipole Study